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SPARK PLUG FOR AN INTERNAL COMBUSTION ENGINE  
[Nainen kikan you supa-ku puragu]

TAKAFUMI OHSHIMA

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INVENTOR	(72): TAKAFUMI OHSHIMA
APPLICANT	(71): JAPAN SPECIAL CERAMIC CO., LTD.
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(72) Inventor: Takafumi Ohshima Japan Special Ceramic Co., Ltd., 14-18 Takatsuji-cho, Mizuho-ku, Nagoya-shi, Aichi Prefecture

(71) Applicant: Japan Special Ceramic Co., Ltd., 14-18 Takatsuji-cho, Mizuho-ku, Nagoya-shi, Aichi Prefecture

(74) Deputy: Patent attorney Miyuki Fujiki

#### Detailed Statement

##### 1. Name of the invention

Spark plug for an internal combustion engine

##### 2. Patent request range

(1) A spark plug for an internal combustion engine, in which, after inserting an ignition electrode made of a noble metal into a hole on a central electrode, by applying tri-axial compressive stress around the above indicated hole on the central electrode, the inner periphery of the hole of the central electrode is plastically deformed by which the central electrode fits into the ditches prepared on the outer periphery of the noble metal ignition electrode and generates a binding between the two electrodes.

(2) A spark plug for an internal combustion engine as described in the request item (1), for which the gap between the hole created on the tip part of the central electrode and the noble metal ignition electrode is kept below 0.05 mm, the solidity of the central electrode lower than Hv170, and the solidity of the noble metal used for the ignition electrode is made to be higher than Hv150.

(3) A spark plug for an internal combustion engine as described in the request item (1), for which at least two out

of the ditches created on the outer periphery of the ignition electrode made of a noble metal are to be embedded in the hole of the central electrode.

(4) A spark plug for an internal combustion engine as described in the request items (1), (2), and (3), in which the diameter A of the ignition electrode made of a noble metal inserted into the hole of the central electrode to be  $0.5 \leq A \leq 1.0$  mm, the ditch range B to be  $B \leq 0.6$  mm, the ditch width C to be  $0.03 \leq C \leq 0.08$  mm, the ditch depth D to be  $0.03 \leq D \leq 0.06$  mm, and the ditch interval E to be  $E \leq 0.05$  mm.

(5) A spark plug for an internal combustion engine as described in the request items (1), (2), (3), and (4), in which thermal treatment is made on the inner periphery of the plastically deformed hole of the central electrode that fits into the ditches, in order to form an alloy layer between the former and the outer periphery of the ignition electrode made of a noble metal.

### 3. Detailed description of the invention

(Considered area of application)

The present invention concerns a spark plug used for an internal combustion engine.

(Conventional technology)

Recently associated with the increase in the output power of internal combustion engines, there are requests for the durability of spark plugs for internal combustion engines.

To meet this goal, there are spark plugs in which an ignition electrode made of a noble metal that has good frictional wear resistance is welded at the tip of a central electrode by means of electric resistance welding or laser welding.

(Problem that the invention attempts to solve)

In the case of the conventional method described above in which an ignition electrode made of a noble metal that has good frictional wear resistance is welded to the tip of the central electrode by means of electric resistance welding or laser welding, a great amount of manufacturing time is required. Furthermore, in the case of using laser welding, it is extremely difficult to determine the set-up conditions because the laser used for welding is high energy, and since it becomes necessary to allocate staff to take care of the tools for welding, there is a marked increase in the production cost. The conventional, mass production method thus comprises difficulties. On the other hand, while improving the drawbacks of the conventional method, the present invention provides a spark plug for an internal combustion engine that consists of an ignition electrode made of a noble metal that has good frictional wear resistance by means of welding with methods such as low-cost press processing.

(Method that solves the problem)

To meet the goal, the central electrode made of nickel alloy is perforated at its tip, in which a cylindrical ignition electrode made of a noble metal is inserted. The ignition electrode has a number of ditches on its outer periphery. The gap between the hole created on the tip of the central electrode and the noble metal ignition electrode inserted into this hole is set to be below 0.05 mm. The solidity of the above-mentioned central electrode and the noble metal used for the ignition electrode is respectively set below Hv170 and above Hv150. In addition, at least two of the ditches created on the outer periphery of the ignition electrode are to be embedded in the hole of the central electrode. The diameter A of the ignition electrode made of a noble metal inserted into the hole of the central electrode to be  $0.5 \leq A \leq 1.0$  mm, the ditch range B to be  $B \leq 0.6$  mm, the ditch width C to be  $0.03 \leq C \leq 0.08$  mm, the ditch depth D to be  $0.03 \leq D \leq 0.06$  mm, and the ditch interval E to be  $E \leq 0.05$  mm. After inserting the ignition electrode made of a noble metal into the hole on the

central electrode, by applying tri-axial compressive stress around the above-indicated hole on the central electrode, the inner periphery of the hole of the central electrode is plastically deformed by which the central electrode fits into the ditches prepared on the outer periphery of the noble metal ignition electrode and generates binding between the two electrodes. By applying thermal treatment on the inner periphery of the plastically deformed hole of the central electrode that fits into the ditches, an alloy layer is formed between the former and the outer periphery of the ignition electrode made of a noble metal.

(Action)

Thanks to the specific structure as described above, when the cylindrical ignition electrode made of a noble metal of solidity above Hv150 and having a number of ditches on its outer periphery is inserted into the hole created in the tip part of the central electrode made of nickel alloy of solidity below Hv170, and when tri-axial compressive stress is applied around the above-indicated hole on the central electrode, the inner periphery of the hole of the central electrode whose solidity is below Hv170 is plastically deformed with respect to the ditches prepared on the outer periphery of the ignition electrode made of a noble metal. The material of the inner periphery of the central electrode made of nickel alloy as described above shall consequently fill in the ditches, thus welding the ignition electrode to the central electrode. Furthermore, by applying thermal treatment on the inner periphery of the plastically deformed hole of the central electrode that fits into the ditches, an alloy layer is formed between the former and the outer periphery of the ignition electrode made of a noble metal, reinforcing the welding.

(Performance example)

The present invention is further explained with a performance example displayed in the figures. (1) represents a spark plug for an internal combustion engine of the performance example, which is made of nickel alloy (such as Inconel 600) or Si-Cr-Mn-95%Ni and encloses a copper core. In the hole (4) situated at its tip, a cylindrical ignition electrode (5) made of a noble metal (such as Pt, Au-Pd alloy, Pt-Ir alloy, Pt-Ni alloy, Ir or Pt/Ni clad wires) and having a number of ditches (6) on its outer periphery is welded and fixed. The spark plug also

consists of a central electrode (3) that is inserted and kept in an insulator (2), the main metallic body (7) equipped with a screw (8) at its tip, and an outer electrode (9).

The cylindrical ignition electrode (5) made of a noble metal that is welded and fixed to the hole (4) created at the tip of the central electrode (3) is inserted in the hole (4) with a gap of less than 0.05 mm to the hole. The solidity of the central electrode described above is lower than Hv170, while that of the noble metal used for the ignition electrode (5) is higher than Hv150. If the solidity of the central electrode (3) is higher than Hv170, there will be a problem that the material of the central electrode shall not be perfectly absorbed into the ditches (6) because of insufficient plastic deformation. On the other hand, if the solidity of the ignition electrode is lower than Hv150, no strong welding will be obtained because of the deformation of the ignition electrode. As a manufacturing process, the cylindrical ignition electrode (5), which is made of a noble metal as described above is first inserted into the hole (4) at the tip of the central electrode (3) and fixed with a fixer (15) around the hole (4) of the central electrode (3). With a punch (16) that is fitted to the fixer (15) and a guide (17), tri-axial stress is applied (in the direction indicated with arrows) around the above-described ignition electrode (5) and generates plastic deformation on the inner wall (10) of the hole (4) of the central electrode (3), whose solidity is less than Hv170. By letting the material on the inner wall of the central electrode (3) fill in the ditches (6) created on the outer periphery of the cylindrical ignition electrode, which is made of a noble metal as indicated above, there will be residual stress that remain because of compression on the welding plane, which welds and fixes the ignition electrode firmly to the central electrode. In addition, by embedding at least two of the ditches (6) created on the outer periphery of the cylindrical ignition electrode made of a noble metal, which is inserted into the hole (4) situated at the tip of the central electrode (3), the welding between the ignition electrode and the central electrode is reinforced when tri-axial stress is applied with the fixer (15) and the punch (16). By taking the dimensions of the ignition electrode described above (5) to be such that the diameter A to be  $0.5 \leq A \leq 1.0$  mm, the ditch (6) range B to be  $B \leq 0.6$  mm, the ditch (6) width C

to be  $0.03 \leq C \leq 0.08$  mm, the ditch (6) depth D to be  $0.03 \leq D \leq 0.06$  mm, and the ditch (6) interval E to be  $E \leq 0.05$  mm, the filling in of the ditch (6) because of the plastic deformation becomes optimal and sufficient welding strength can be obtained. After inserting the cylindrical ignition electrode (5) made of a noble metal into the hole (4) created at the tip of the central electrode (3), plastic deformation caused by applying tri-axial compressive stress allows the material of the central electrode to fill in the ditches (6). In addition to this, a thermal treatment at  $1000^{\circ}\text{C}$  over two hours allows an alloy layer (14) to be formed, such as that of Pt-Ni, in between the inner wall (10) of the hole (4) of the central electrode (3) and the outer periphery of the ignition electrode (5), which furthermore reinforces the welding. Now, the spark plug for an internal combustion engine of the performance example (1) was integrated into an actual 6-cylinder 2000 cc engine, to test the repetition of cooling and heating of the engine. The engine was altered between two states each lasting over a minute, of idling and full rotation at 5000 rpm, where no anomaly such as exfoliation was encountered, demonstrating the effectiveness of the present invention. As regards the ditches (6) on the outer periphery of the ignition electrode (5) with a punch, they can either be processed locally or all around the periphery, and in addition, they could also be roulette processed. (11) represents an electrically conducting glass that supports the resistance (12), and is thermally attached within the insulator (2) along with the terminal electrode (13).

(Impact of the invention)

As described above, the spark plug of the present invention consists of a central electrode made of nickel alloy, at the tip of which a hole is prepared through which an ignition electrode made of a noble metal and having ditches on its outer periphery is inserted. By applying compressive stress around it, plastic deformation is generated on the central electrode and its material is filled into the ditches prepared on the outer periphery of the above indicated ignition electrode. In this way, welding can be made simply with a compressor. The present invention furthermore allows materials having a high melting point such as iridium to be used for the ignition electrode, and thus provides an effective method of

creating a spark plug having excellent frictional wear resistance.

#### 4. Brief explanations of the figures

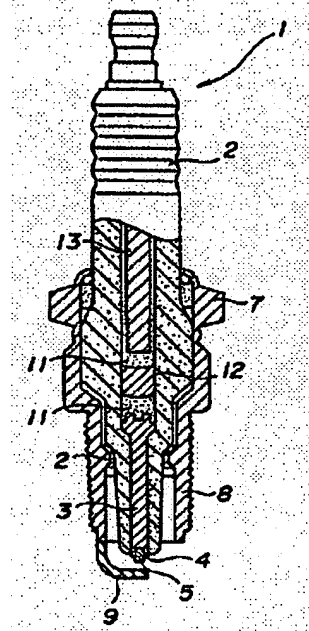
Fig. 1 illustrates a partial cross section of the spark plug for an internal combustion engine of the performance example of the present invention. Figs. 2 represent amplified cross sections of parts of Fig. 1.

In addition, Figs. 3 illustrate cross sections that indicate the manufacturing process of parts of the spark plug for an internal combustion engine of the performance example.

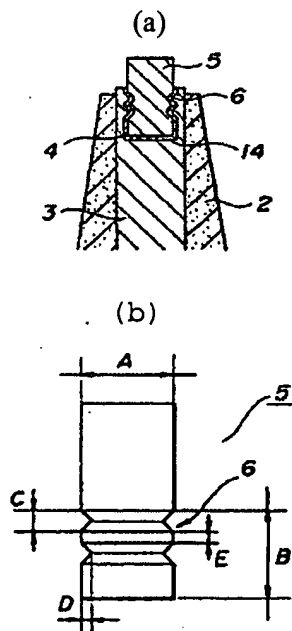
1...Spark plug for an internal combustion engine. 2...Insulator. 3...Central electrode. 4...Hole part. 5...Ignition electrode. 6...Ditches. 7...Main metallic body. 8...Screw part. 9...Outer electrode. 10...Inner wall. 11...Electrical conducting glass. 12...Resistance. 13...Terminal electrode. 14...Alloy layer. 15...Fixer. 16...Punch

Patent applicant: Deputy Patent attorney Miyoshi Fujiki

Fig. 1



Figs. 2



Figs. 3

